TECHNICAL REPORT GL-90-2

LAND LOSS RATES

Report 2
LOUISIANA CHENIER PLAIN

by

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November 1990
Report 2 of a Series

Prepared for US Army Engineer District, New Orleans
New Orleans, Louisiana 70160-0267

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1990	Report 2 of a Series

4. TITLE AND SUBTITLE
Land Loss Rates; Report 2, Louisiana Chenier Plain

5. FUNDING NUMBERS

6. AUTHOR(S)
Joseph B. Dunbar, Louis D. Britsch, E. Burton Kemp III

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USAE Waterways Experiment Station, Geotechnical Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6299; US Army Engineer District, New Orleans, PO Box 60267, New Orleans, LA 70160-0267

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Engineer District, New Orleans
PO Box 60267
New Orleans, LA 70160-0267

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
Technical Report GL-90-2

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Land loss mapping and rate curve development for 12 US Geological Survey (USGS) topographic quadrangles in the Louisiana Chenier Plain indicate that the magnitude and trend in land loss rates are highly variable. Two of the 12 quadrangles comprising the chenier plain show an increase in the land loss rate when comparing the middle period (1950's to 1974) to the most recent period (1974 to 1983). Three quadrangles have a constant rate. In the remaining seven quadrangles, the rate is decreasing. Differences in land loss rates among the individual quadrangles are a function of the geologic setting and the factors which contribute to land loss such as subsidence, storm-induced erosion, channelization of rivers and streams, and canal dredging. Specific causes of land loss are not evaluated in this study.

Land loss rates for the entire chenier plain are presently decreasing from the their high estimated to have occurred during the early 1970's. The average land loss rate as of 1983 for the chenier plain is 7.74 square miles per year. On a

(Continued)

14. SUBJECT TERMS
Land loss
Louisiana Chenier Plain
Mississippi River deltaic plain
Wetland loss
Wetlands

15. NUMBER OF PAGES
38

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	

13. (Concluded).

regional scale, the land loss rate for the entire Mississippi River Deltaic and Chenier Plains is decreasing. The average land loss rate as of 1983 for the combined Mississippi River Deltaic and Chenier Plains (an area comprising 62 USGS topographic quadrangles) was 30.71 square miles per year. At its peak, approximately in the early 1970's, the average land loss rate was 41.88 square miles per year. Another data point is necessary to determine whether this decrease is continuing.

Land lose date generated during this investigation are being combined with geologic data in a Geographic Information System to conduct detailed analyses of the causes of land lose in future reports.

Keywords: Sediment transport; Land areas/loss; Soil erosion; Topographic maps; Coastal regions/ridges; Canals/dredging; Natural levees/deltas; Channels/waterways; Sandbars.

PREFACE

This investigation was authorized by the US Army Engineer District, New Orleans (CELMN), under the heading "Land Loss Mapping and Rate Curve Development: Louisiana Chenier Plain" by DA Form 2544, Number CELMNED-90-01, dated 4 October 1989.

This investigation was performed and the report prepared during the period 4 October 1989 to 5 October 1990. The program manager for this study was Mr. E. B. Kemp III, Chief, Geology Section, Engineering Division, CELMN. Land loss mapping and rate curve development were performed by Mr. J. B. Dunbar, Geologic Environments Analysis Section (GEAS), Engineering Geology Branch (EGB), Earthquake Engineering and Geosciences Division (EEGD), Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES), and Mr. L. D. Britsch, Geology Section, Engineering Division, CELMN. This report was prepared by Messrs. Dunbar, Britsch, and Kemp.

This investigation was conducted under the direct supervision of Mr. R. J. Larson, Chief, GEAS and EGB, and under the general supervision of Drs. A. G. Franklin, Chief, EEGD, and W. F. Marcuson III, Chief, GL.

COL Larry B. Fulton, EN, was Commander and Director of WES during the preparation of this report. Dr. Robert W. Whalin was Technical Director.

CONTENTS

LAND LOSS RATES: LOUISIANA CHENIER PLAIN

PART I: INTRODUCTION

Background

1. This study is the second study by the US Army Engineer District, New Orleans (CELMN), and the US Army Engineers Waterways Experiment Station (WES) on land loss rates in coastal Louisiana. In the first study, Britsch and Kemp (1990) defined land loss rates for 50 US Geological Survey (USGS) 15-min (1:62,500 scale) quadrangles within the Mississippi River Deltaic Plain. Land loss rate curves were presented for these individual quadrangles, and a composite land loss rate curve was compiled for the entire study area. Results of the study by Britsch and Kemp indicate that land loss rates in coastal Louisiana are not as excessive as previously reported (Gagliano, Meyer-Arendt, and Wicker 1981; Penland and others 1989). A detailed review and summary of previous land loss studies conducted to date in coastal Louisiana will not be presented in this report as it was presented by Britsch and Kemp (1990). This study is a continuation of the land loss mapping and rate curve development initiated by Britsch and Kemp. This study mapped historic land loss and determined land loss rates for the Louisiana Chenier Plain.

General Setting and Geomorphology

2. Shifting Mississippi River deltas during the past 7,000 years have created the Louisiana Chenier Plain. Nearshore transport and deposition of fine grained sediments supplied by the different Mississippi River delta systems during this time are responsible for creating the vast expanse of coastal marshlands which form the chenier plain. The resulting landscape consists of alternating mudflats, marsh, and long, narrow, coast-parallel sandy ridges that support oak dominated forests (Bates and Jackson 1980). The name chenier is derived from the French word "chene" for oak. Chenier ridges are formed by longshore drift of deltaic sediments and the reworking of these sediments by coastal processes after deposition. Cycles of erosion and deposition are due to shifting delta systems and the resulting sediment

available from longshore drift. Erosion of the shoreline concentrates the coarse sediments contained within the mudflats with shell debris to form ridges that are characteristic of the chenier plain. Later, as the shoreline aggrades as a result of an influx of sediment, these ridges become isolated, stranded beach ridges.

3. Since the early 1900's, the general trend of land building in both the deltaic and chenier plains has been reversed. Louisiana's coastal zone is losing land at a high rate (Britsch and Kemp 1990). Causes for this loss range from man's activities (i.e., canal dredging, channelization of streams and rivers, and hydrocarbon extraction) to various natural phenomena such as subsidence, shoreline erosion, and subsurface geologic control (i.e., faulting).

Purpose and Scope

4. The purpose of this study was to document on maps the land loss that has occurred in the Louisiana Chenier Plain since the mid 1930's and determine the magnitude of that loss. Specific objectives of this study were to map land loss over three continuous time periods for each 15-min (1:62,500) USGS quadrangle in the study area, determine a land loss rate for each quadrangle mapped, determine a land loss rate for the entire chenier plain, and determine a regional land loss rate for the entire Louisiana coastal plain. Major tasks performed during this study include land loss mapping from aerial photographs, measuring and calculating land loss areas from the base maps, deriving a land loss rate for each quadrangle in the study area as well as a composite land loss rate for both the chenier plain and the entire Louisiana coastal plain, and data analyses and report preparation. This report will not evaluate the causes of land loss in the chenier plain. Future reports will address site specific land loss and its causes.

Study Area

5. The study area is contained on twelve 15-min USGS quadrangle maps shown in Figure 1. Each land loss map was assigned the name of the corresponding USGS quadrangle map as identified in Figure 1.

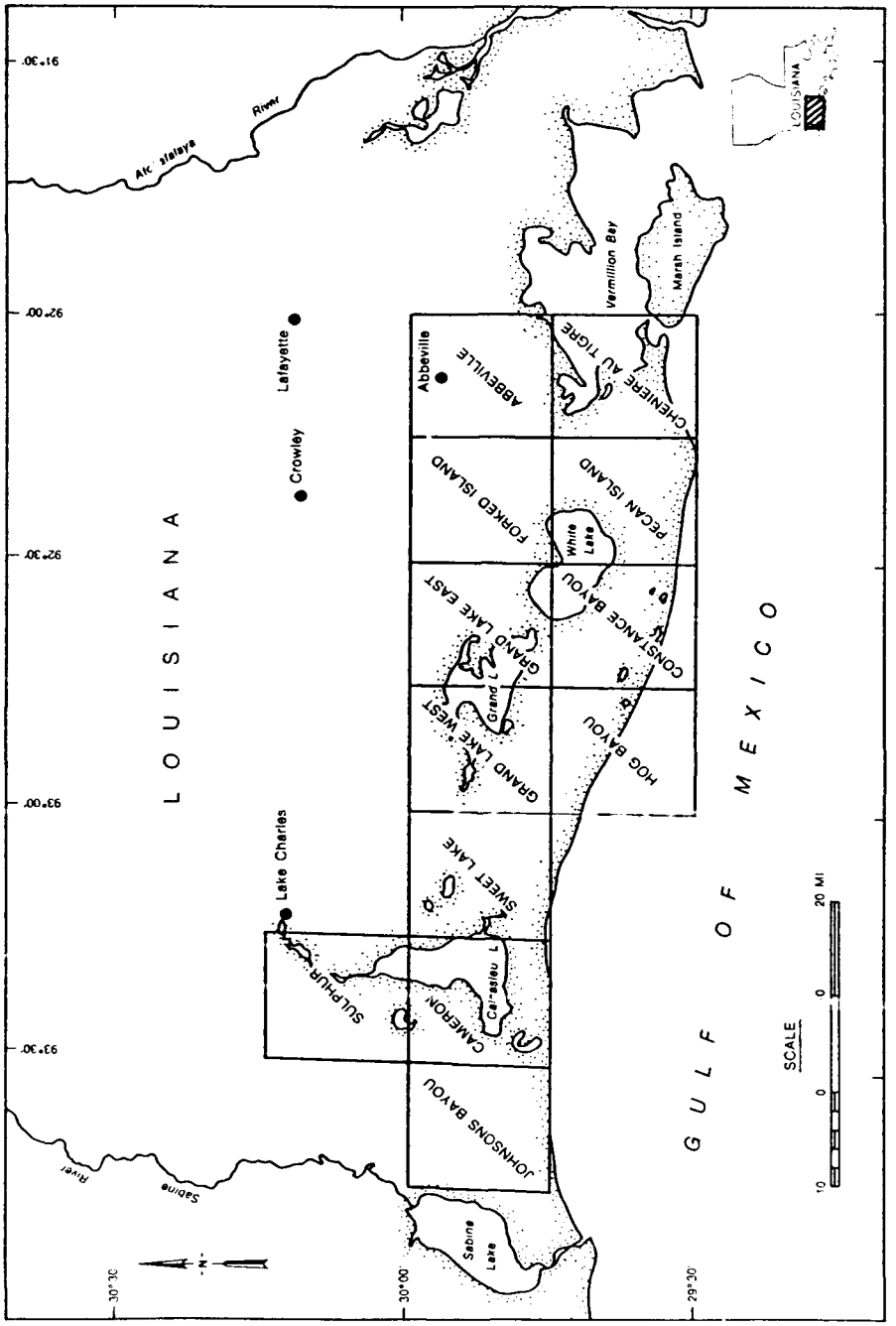

Figure 1. Location and index map to the Louisiana Chenier Plain

PART II: DATA SOURCES AND MAPPING PROCEDURES

Data Sources

6. Land loss mapping was accomplished by comparing four vintages of aerial photography to a base map and delineating the land loss which had occurred over the period of record on the base map. Sources of map and photographic data used in this study to conduct land loss mapping are identified in Table 1.

7. Base maps showing land loss changes were prepared either from US Coast and Geodetic Survey Air Photo Compilation Sheets (T-sheets) or from early USGS 15-min topographic quadrangle maps. Both types of base maps were derived from interpretation of early aerial photography. T-sheets were the preferred base map for this study as they are the earliest and most comprehensive base map available for Louisiana's coastal plain. T-sheets were photographically reduced to a USGS 15-min (1:62,500) quadrangle map format for mapping. However, T-sheets were not available for the entire chenier plain study area. In the chenier plain, approximately 25 percent of the land loss mapping was conducted on T-sheets. The T-sheets used in this study were published in 1932. The remaining area was mapped on the earliest available USGS 15-min topographic quadrangle map. These base maps ranged from 1951 to 1956.

Land Loss Interpretation and Classification

8. This study documents changes from land to water in the Louisiana Chenier Plain over a period of approximately 50 years. Land loss was considered to be any land area present on either the 1930's photography or base maps that were interpreted as water on later photographic and map coverages. Land loss identified during the mapping includes both loss from man-made causes as well as loss due to natural processes. Most of the land loss classified as man-made is the result of dredging activity for various types of canals and waterways designed to aid navigation. All land loss not the direct result of man's activities was considered natural loss.

9. Because the distinction between land and water is so critical to the accuracy of this study, it is important to identify the criteria used to

Table 1
Source and Description of Map and Photographic Products

Date	Source	Original Scale
1932	US Coast and Geodetic Survey Air Photo Compilation Sheets (T-sheets)	1:20,000
1933-35	Tobin Surveys, Black-and-White Quadrangle Centered Aerial Photo Mosaics	1:24,000
1951-55	US Geological Survey Maps 15-Minute Topograhic Quadrangles	1:62,500
1956-58	Tobin Surveys, Black-and-White, Quadrangle Centered Aerial Photo Mosaics	1:24,000
1974	NASA Color IR Photography	1:20,000
1983	National High Altitude Program, Color IR Photography	1:58,000

distinguish between land and water. Water was classified as any area of water having no permanent vegetation visible at the surface. Permanent vegetation, for purposes of this investigation, is that which is attached to the substrate, not floating vegetation such as hydrilla and hyacinths. Land was simply defined as everything on the photography (or base map) not classified as water. Generally, the only land features on the photography without some visible vegetation were some beaches, mudflats, and dredged materials.

Land Loss Mapping and Area Measurement

10. A detailed discussion of the methods and different steps used to map land loss in this study is omitted from this report as it was described in detail by Britsch and Kemp (1990). In summary, land loss mapping in the chenier plain consisted of comparing land areas on an overlay base map (transparent film positive of 15-min USGS quadrangle map) to land areas on the photographic period selected and delineating areas of land loss on the overlay base map. Land loss was delineated for each photographic period examined beginning with the earliest photographic coverage and ending with the most recent. The resulting land loss map identified the overall land loss changes that had occurred over the period of record, identified these changes according to when the change occurred, and whether it was man-made (i.e., pipe lines and canals) or natural loss.

11. Areas of mapped land loss were measured and area calculations made to quantify the land loss changes that occurred during each period for each map in the study area. Measurement of land loss areas was conducted by computer scanning of individual overlays prepared for each map. Six black ink overlays were prepared for each map representing the natural and man-made land loss identified for each period. These attribute maps were computer scanned to derive a land loss acreage value for each overlay map. Area calculations were then tabulated to determine a land loss rate for each period and to prepare a rate curve for each quadrangle. Examples of the different steps involved in land loss mapping and additional information about the procedures required to derive land loss rate data are described in more detail by Britsch and Kemp (1990).

PART III: LAND LOSS RATES

Land Loss Rates of Individual Quadrangles

12. Land loss rates for the 12 USGS quadrangle maps in the Louisiana Chenier Plain are shown in Table 2, and rate curves for these quadrangles are presented in Appendix A. Time periods over which the land loss rates are based are shown in Table 2 and graphically by horizontal bars on the land loss rate curves (see Appendix A). Land loss rates shown on the rate curves in Appendix A were plotted at the midpoint of the time span for each period.

13. Land loss rates in the chenier plain are highly variable as shown in Table 2. General land loss trends are shown in Figure 2. Three quadrangles show a constant (less than 10 percent change) land loss rate, seven quadrangles show a decreasing rate, and two quadrangles show increasing rates. For quadrangles to be classified as having increasing or decreasing change, a 10 percent or more rate change was required between the middle time period (1950's to 1974) and the last time period (1974 to 1983).

Composite Land Loss Rate

Chenier Plain

14. A composite land loss rate curve for the entire chenier plain is shown in Figure 3. The composite rate curve represents the average land loss rate (in square miles per year) for each time period. Land loss rates in the chenier plain were greatest for the middle time period (1950's to 1974). The loss rate decreased for the last period. This trend is consistent with land loss rates in the Mississippi River Deltaic Plain (Britsch and Kemp 1990).

Mississippi River Deltaic Plain

15. A combined rate curve for the Mississippi River Deltaic and Chenier Plains (Figure 4) is presented in Figure 5 (after Britsch and Kemp 1990). This rate curve represents the combined loss for 62 USGS 15-min quadrangles. Land loss rates for the different Mississippi River deltaic plain quadrangles shown in Figure 4 are presented in Table 3 (from Britsch and Kemp 1990). The composite rate for both the deltaic and chenier plains is consistent with trends identified for these areas individually.

Table 2
Louisiana Chenier Plain
Land Loss Rates Derived from Area Calculations

Quadrangle* Name	Time Period 1	Average Loss* in Square Mile/year	Time Period 2	Average Loss* in Square Mile/year	Time Period 3	Average Loss* in Square Mile/year
Abbeville	1935-1954	0.075	1954-1974	0.245	1974-1983	0.255
Cameron	1933-1955	0.077	1955-1974	2.468	1974-1983	0.596
Cheniere Au Tigre	1935-1951	0.076	1951-1974	0.358	1974-1983	0.127
Constance Bayou	1932-1955	0.641	1955-1974	0.822	1974-1983	0.495
Forked Island	1935-1955	0.019	1955-1974	0.152	1974-1983	0.145
Grand Lake East	1932-1955	0.324	1955-1974	0.438	1974-1983	1.643
Grand Lake West	1933-1955	0.048	1955-1974	1.116	1974-1983	1.302
Hog Bayou	1932-1955	0.537	1955-1974	0.723	1974-1983	0.151
Johnsons Bayou	1933-1955	0.088	1955-1974	3.119	1974-1983	1.022
Pecan Island	1935-1951	0.063	1951-1974	0.792	1974-1983	0.752
Sulphur	1933-1955	0.047	1955-1974	1.823	1974-1983	0.395
Sweet Lake	1933-1955	0.129	1955-1974	1.796	1974-1983	0.839

* Approximate area of a 15-min quadrangle is 300 square miles.

CHENIER PLAIN
LAND LOSS RATE TREND

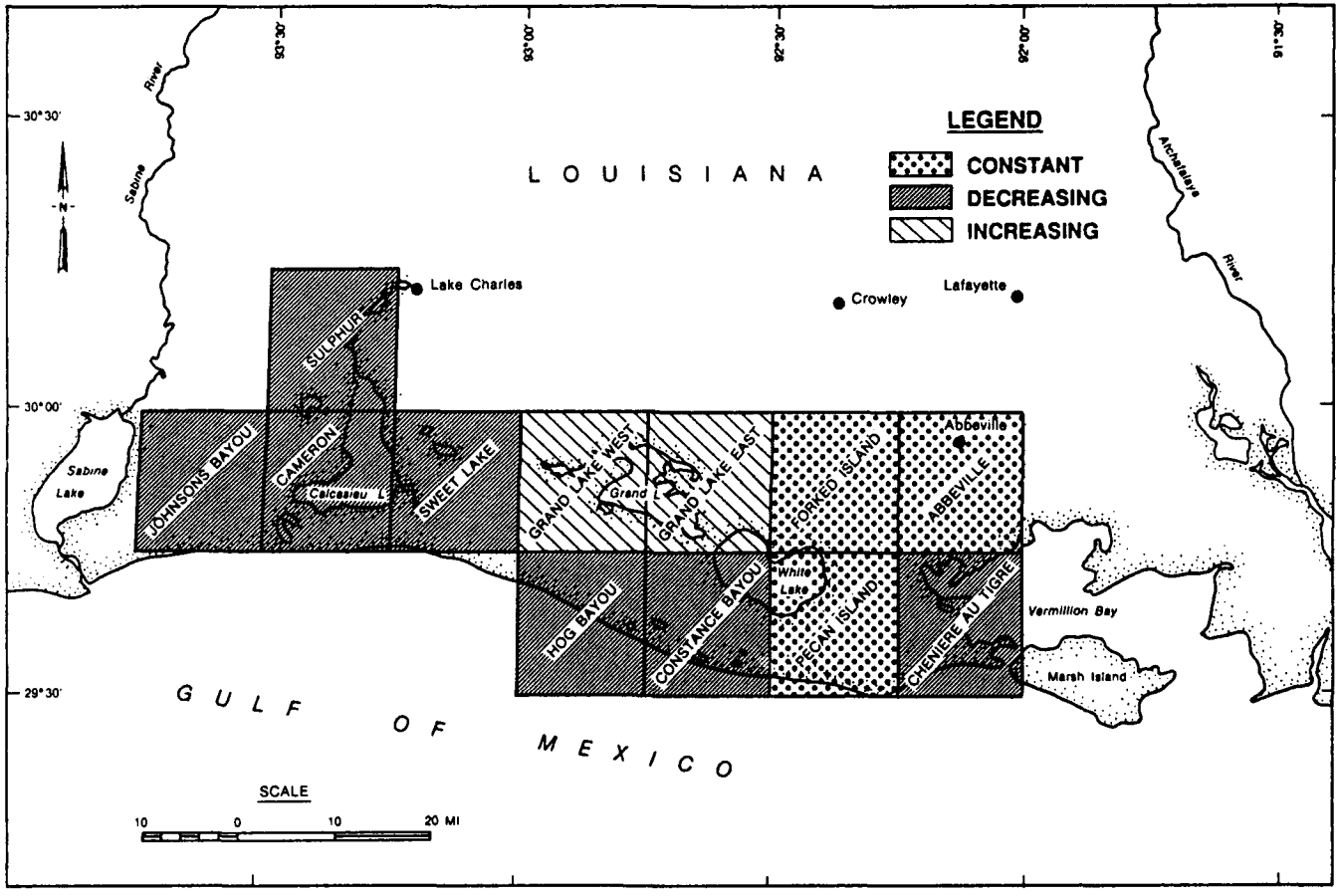

Figure 2. Land loss rate trends: constant rate indicates less than 10 percent change from previous period, decreasing rate indicates amount of decrease was greater than 10 percent from previous period, increasing rate indicates amount of increase was greater than 10 percent from previous period

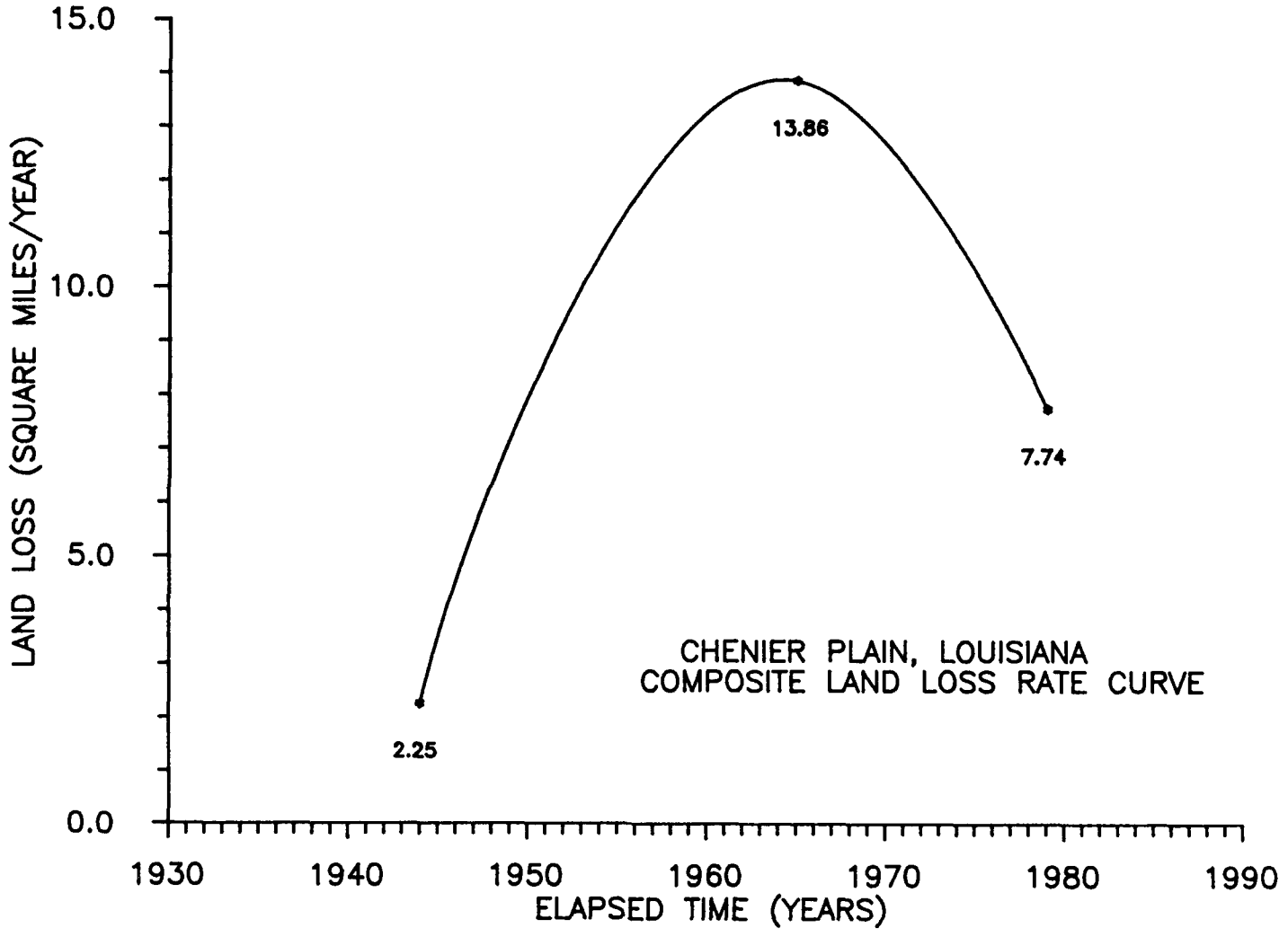

Figure 3. Composite land loss rate curve for the Louisiana Chenier Plain. For purposes of scale and comparison, the approximate land area of a 15-min quadrangle is 300 square miles

LAND LOSS MAPPING

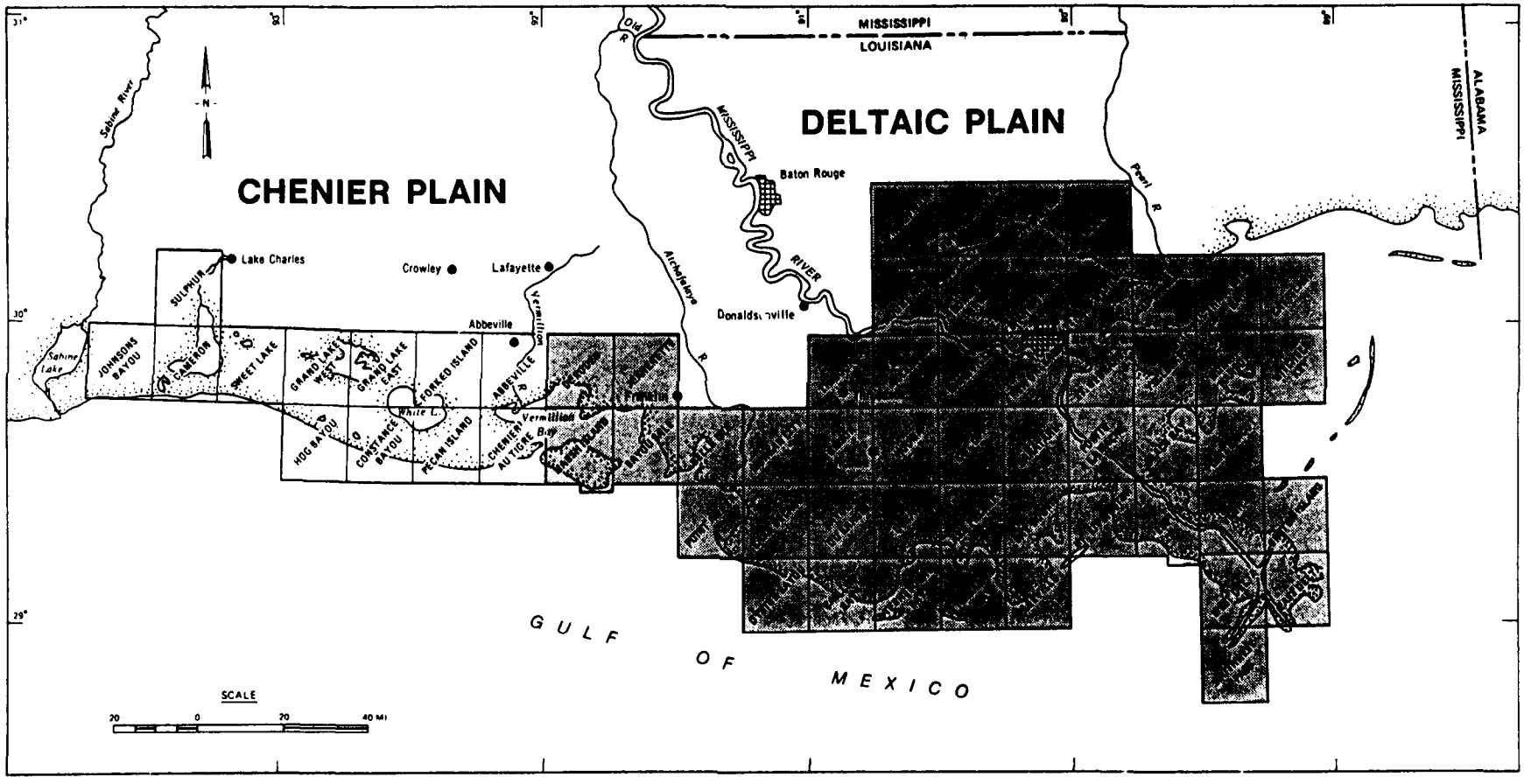

Figure 4. Index map to Louisiana's Coastal Plain quadrangles. Land loss rates for individual quadrangles are presented in Tables 2 and 3.

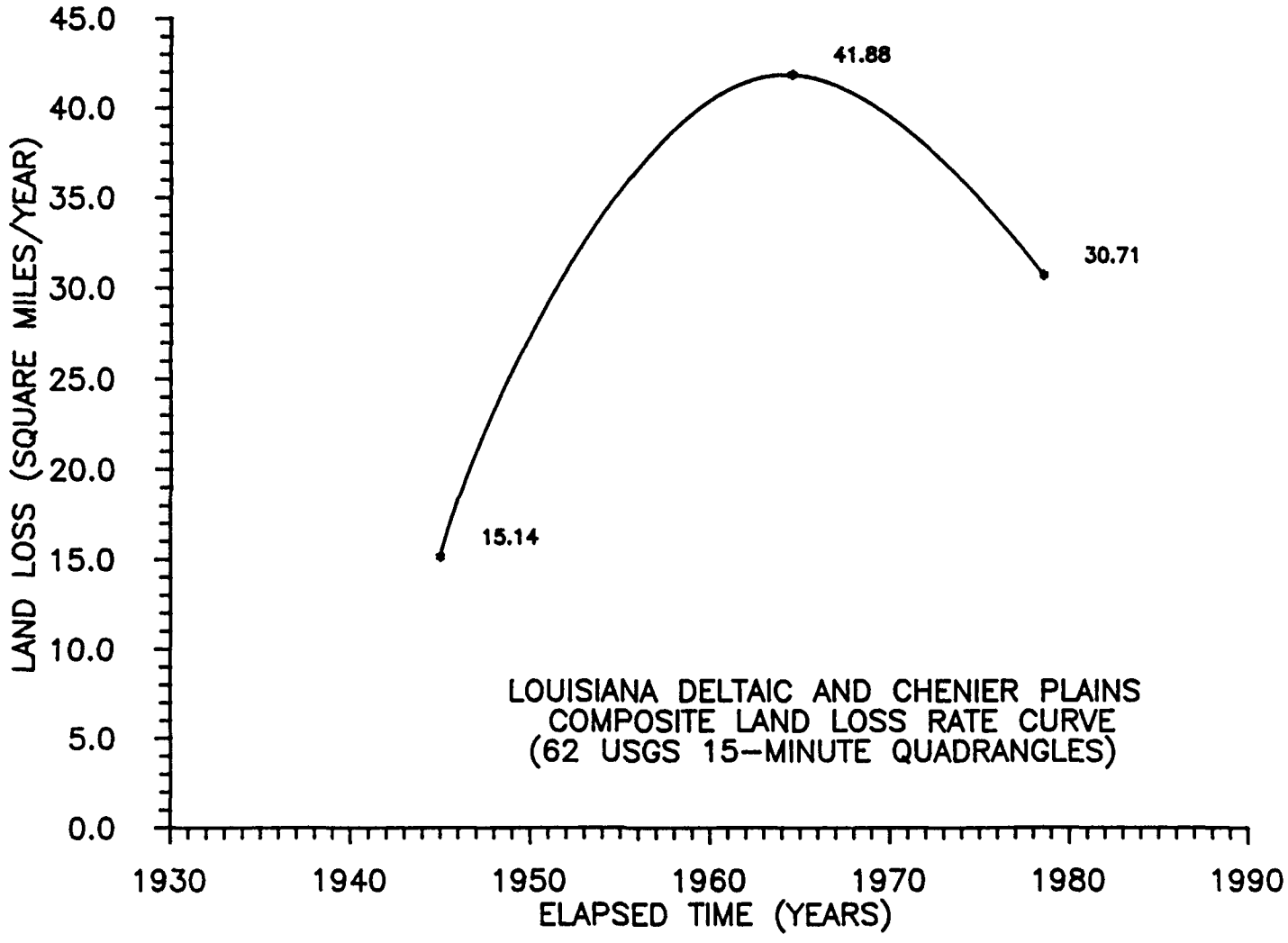

Figure 5. Composite land loss rate curve for Louisiana's Deltaic and Chenier Plains. For purposes of scale and comparison, the approximate land area of a 15-min quadrangle is 300 square miles

Table 3

Mississippi River Deltaic Plain
Land Loss Rates Derived From Area Calculations

Quadrangle Name	Time Period 1	Average Loss in Square Mile/year	Time Period 2	Average Loss in Square Mile/year	Time Period 3	Average Loss in Square Mile/year
Barataria	1939-1956	1.08	1956-1974	1.20	1974-1983	0.70
Bay Dogris	1932-1958	0.42	1958-1974	1.44	1974-1983	1.26
Bayou Du Large	1932-1958	0.18	1958-1974	1.61	1974-1983	0.65
Bayou Sale	1937-1956	0.31	1956-1974	0.36	1974-1983	0.19
Belle Isle	1940-1956	0.38	1956-1974	0.32	1974-1983	0.15
Black Bay	1932-1958	0.21	1958-1974	0.37	1974-1983	0.52
Bonnet Carre	1936-1958	0.10	1958-1974	0.44	1974-1983	0.19
Breton Island	1932-1958	0.26	1958-1974	0.18	1974-1983	0.11
Caillou Bay	1932-1958	0.22	1958-1974	0.40	1974-1983	0.43
Cat Island	1932-1958	0.07	1958-1974	0.09	1974-1983	0.11
Chef Menteur	1932-1958	0.49	1958-1974	0.41	1974-1983	0.28
Covington	1932-1958	0.02	1958-1974	0.18	1974-1983	0.02
Cut Off	1939-1958	0.22	1958-1974	0.53	1974-1983	0.39
Derouen	1932-1956	0.24	1956-1974	0.22	1974-1983	0.24
Dulac	1932-1958	0.37	1958-1974	0.98	1974-1983	1.99
East Delta	1932-1958	1.17	1958-1974	1.90	1974-1983	0.27
Empire	1932-1958	0.35	1958-1974	1.12	1974-1983	2.66
Fort Livingston	1932-1958	0.34	1958-1974	0.53	1974-1983	0.89
Gibson	1939-1958	0.11	1958-1974	1.50	1974-1983	0.45
Hahnville	1935-1958	0.11	1958-1974	0.57	1974-1983	0.43
Houma	1939-1958	0.13	1958-1974	0.24	1974-1983	0.17
Jeanerette	1937-1956	0.08	1956-1974	0.08	1974-1983	0.06
Lac des Allemands	1945-1958	0.13	1958-1974	0.11	1974-1983	0.66
Lake Decade	1931-1956	0.25	1956-1974	1.31	1974-1983	0.38
Lake Felicity	1932-1958	0.29	1958-1974	1.32	1974-1983	1.61
Leeville	1932-1958	0.28	1958-1974	0.40	1974-1983	0.90
Marsh Island	1932-1956	0.23	1956-1974	0.39	1974-1983	0.24
Mitchell Key	1932-1956	0.05	1958-1974	0.03	1974-1983	0.07

(Continued)

Table 3 (Concluded)

Quadrangle Name	Time Period 1	Average Loss in Square Mile/year	Time Period 2	Average Loss in Square Mile/year	Time Period 3	Average Loss in Square Mile/year
Morgan City	1931-1956	0.20	1956-1974	1.37	1974-1983	0.93
Morgan Harbor	1932-1958	0.19	1958-1974	0.32	1974-1983	0.38
Mount Airy	1939-1958	0.05	1958-1974	0.08	1974-1983	0.08
New Orleans	1935-1958	0.17	1958-1974	0.26	1974-1983	0.14
Oyster Bayou	1931-1956	0.07	1956-1974	0.18	1974-1983	0.15
Point Chicot	1932-1958	0.08	1958-1974	0.08	1974-1983	0.07
Point au Fer	1931-1956	0.11	1956-1974	0.16	1974-1983	0.17
Pointe a la Hache	1932-1958	0.28	1958-1974	0.75	1974-1983	0.71
Pontchatoula	1939-1958	0.07	1958-1974	0.09	1974-1983	0.08
Rigolets	1932-1958	0.11	1958-1974	0.24	1974-1983	0.26
Slidell	1939-1958	0.06	1958-1974	0.15	1974-1983	0.05
Southwest Pass	1932-1958	0.10	1958-1974	0.12	1974-1983	0.02
Spanish Fort	1936-1958	0.03	1958-1974	0.01	1974-1983	0.003
Springfield	1939-1958	0.01	1958-1974	0.01	1974-1983	0.03
St. Bernard	1932-1958	0.29	1958-1974	1.23	1974-1983	0.70
Terrebonne Bay	1932-1958	0.18	1958-1974	0.29	1974-1983	0.49
Thibodaux	1949-1958	0.003	1958-1974	0.02	1974-1983	0.07
Three Mile Bay	1932-1958	0.08	1958-1974	0.11	1974-1983	0.10
Timbalier Bay	1932-1958	0.21	1958-1974	0.22	1974-1983	0.41
Venice	1932-1958	0.61	1958-1974	1.50	1974-1983	0.54
West Delta	1932-1958	1.41	1958-1974	2.0	1974-1983	1.04
Yscloskey	1932-1958	0.12	1958-1974	0.60	1974-1983	0.53

16. An updated map showing the recent land loss trend for both the deltaic and chenier plains is presented in Figure 6 (after Britsch and Kemp 1990). As in Figure 2, a rate change of 10 percent was chosen as the value in which to define whether the rate for an individual quadrangle was increasing, decreasing, or remaining the same. There are 10 quadrangles that have constant land loss rates, 16 quadrangles with increasing land loss rates, and 36 quadrangles with decreasing rates.

LAND LOSS RATE TREND

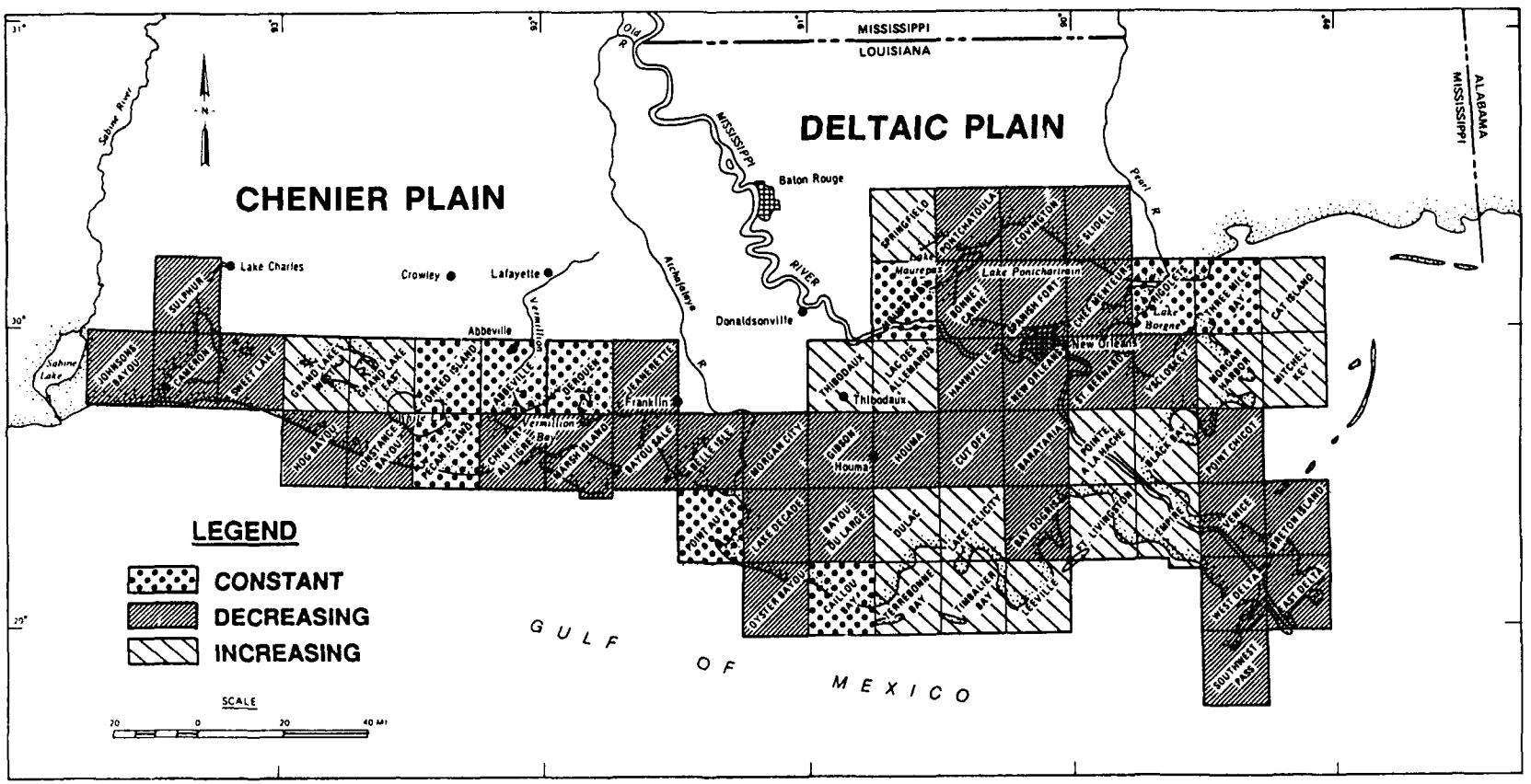

Figure 6. Land loss rate trends for Louisiana's Coastal Plain: constant rate indicates less than 10 percent change from previous period, decreasing rate indicates amount of decrease was greater than 10 percent from previous period, increasing rate indicates amount of increase was greater than 10 percent from previous period

PART IV: CONCLUSIONS

Conclusions

17. Land loss mapping and rate curve development for 12 quadrangles in Louisiana s Chenier Plain indicates that the magnitude of land loss as well as the trend in land loss rates is highly variable. Two of the 12 quadrangles comprising the chenier plain show an increase in the land loss rate when comparing the middle period (1950's to 1974) to the most recent period (1974 to 1983). Three quadrangles have a constant rate. In the remaining seven quadrangles, the rate is decreasing.

18. Land loss rates for the entire chenier plain are presently decreasing from their high estimated to have occurred during the early 1970's. Chenier plain rates are consistent with trends defined by Britsch and Kemp (1990) for the deltaic plain. The average land loss rate as of 1983 for the chenier plain is 7.74 square miles per year.

19. On a regional scale, the land loss rate for the entire Mississippi River Deltaic and Chenier Plains is decreasing. The average land loss rate as of 1983 for the combined Mississippi River Deltaic and Chenier Plains (62 USGS quadrangles) was 30.71 square miles per year. At its peak, approximately in the early 1970's, the average land loss rate was 41.88 square miles per year. Another data point is necessary to determine whether this decrease in the land loss rate is continuing.

20. A detailed discussion concerning the factors responsible for land loss in the Mississippi River Deltaic and Chenier Plains is beyond the scope of this report. Land loss data compiled during this study indicates that many factors contribute. These include, but are not limited to, geologic factors such as faulting, subsidence, geomorphology, depth to Pleistocene, differences in the engineering properties of the various environments of deposition, sediment age, and the hydrologic setting. Man-made factors responsible for land loss such as dredging of canals and navigation waterways, as well as levee construction, also account for a significant portion of the total land loss.

Future Work

21. To effectively address in detail the specific factors mentioned above, the CELMN and WES have developed a Geographic Information System (GIS) to aid in determining regional and site specific land loss rates as well as the causes of land loss (Williamson and Britsch 1989). All of the land loss data generated during this study, as well as the study by Britsch and Kemp (1990), engineering geology and Pleistocene data previously completed by WES, and all published radiocarbon and subsidence data from the deltaic and chenier plains are being assembled and entered into the CELMN and WES GIS.

22. At the present time, the CELMN and WES are planning to conduct a high altitude photographic mission in the winter of 1990 to update the current land loss maps and rate curves from the deltaic and chenier plains. This will enable the CELMN and WES to determine whether land loss rates for the Louisiana coastal zone are increasing or decreasing and provide basic data for determining the various factors responsible for land loss.

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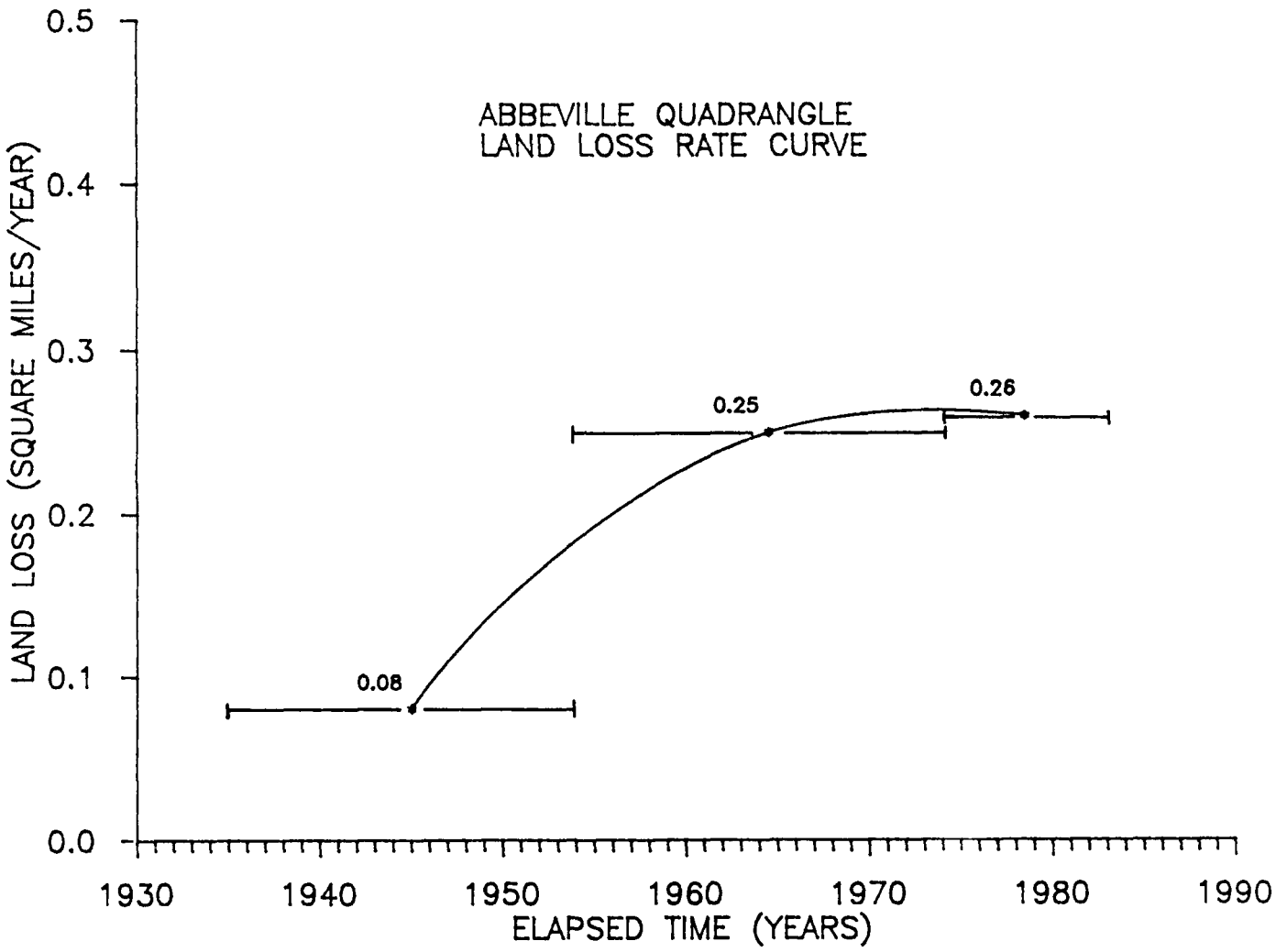
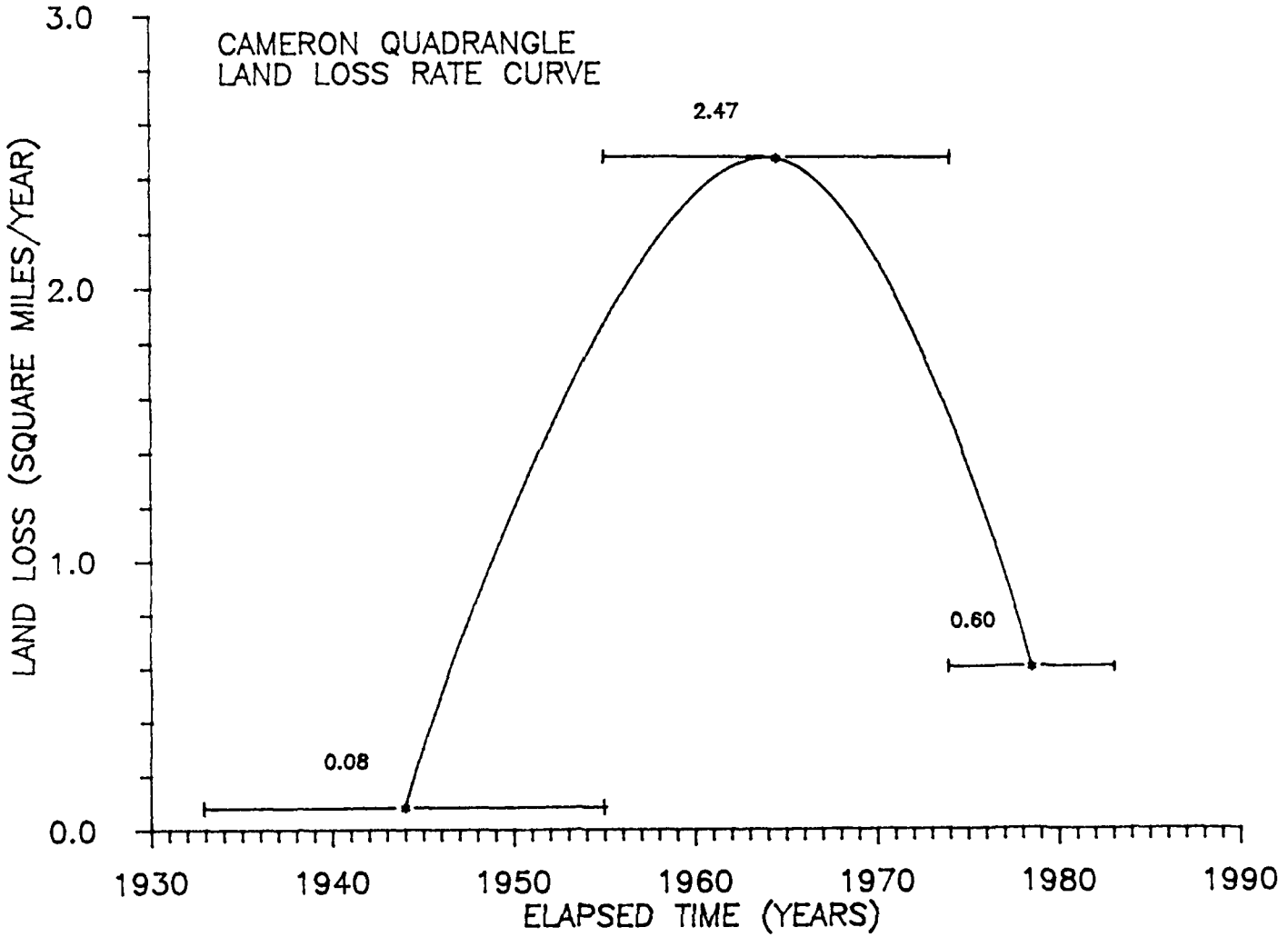
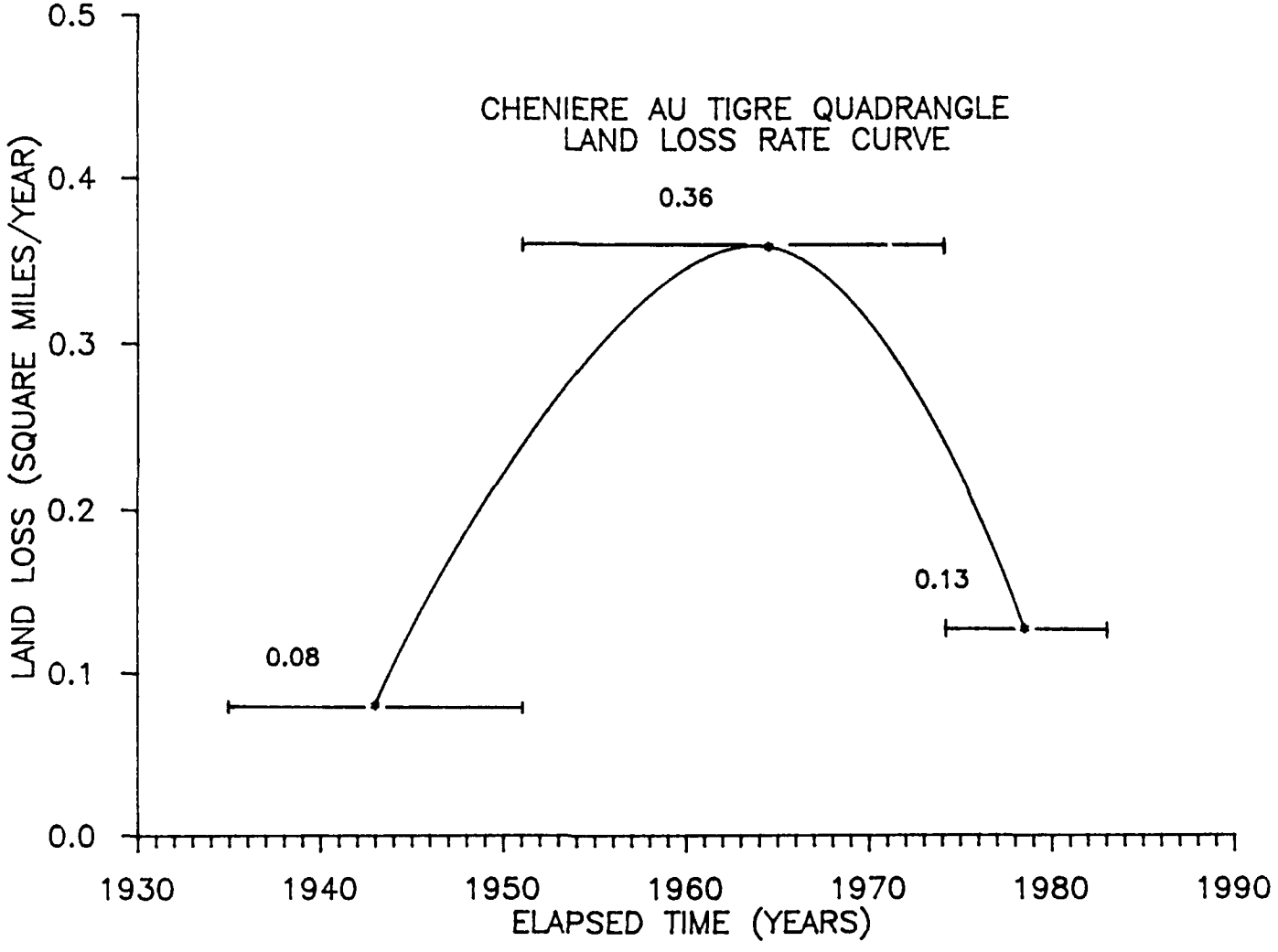
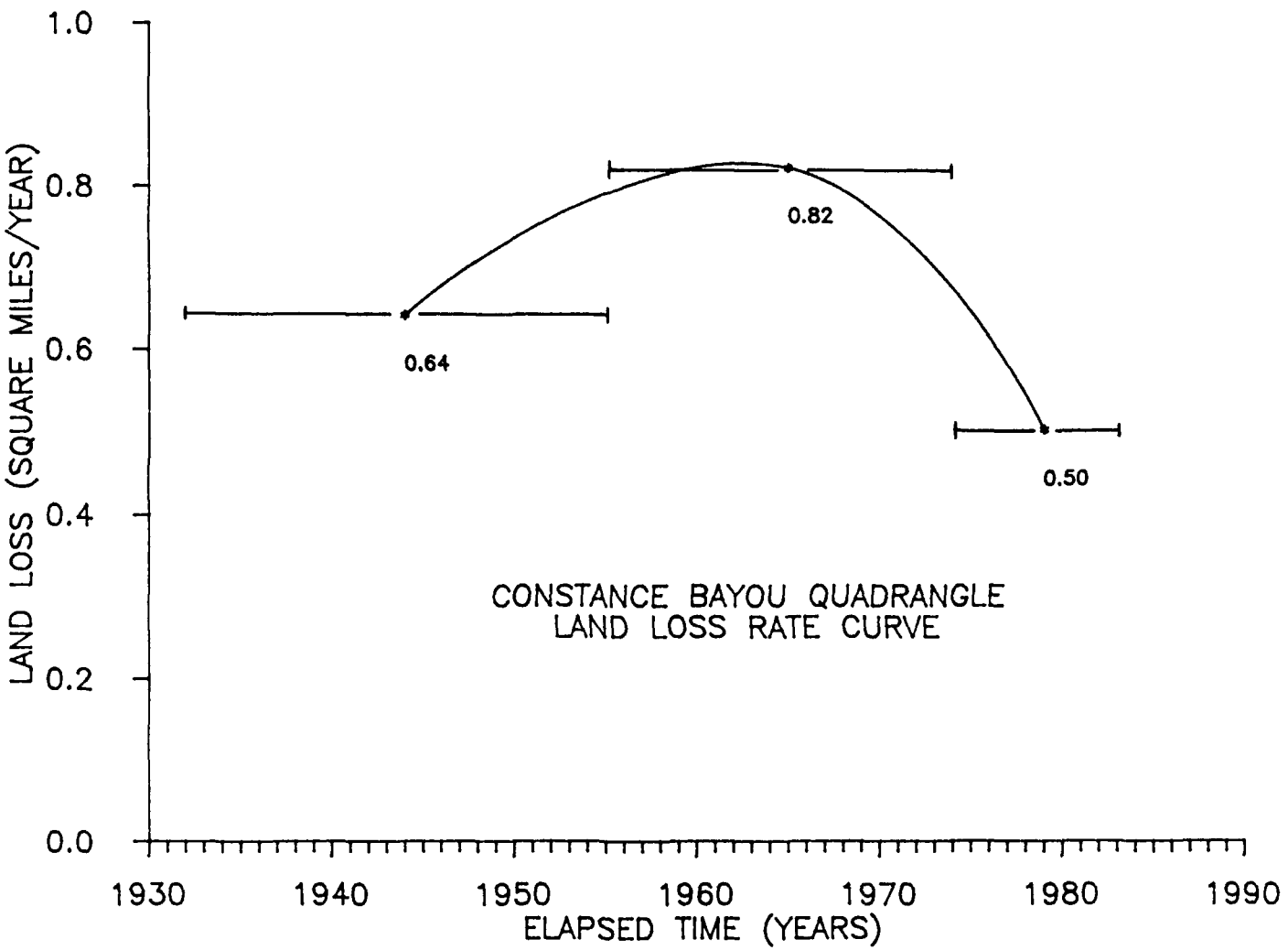
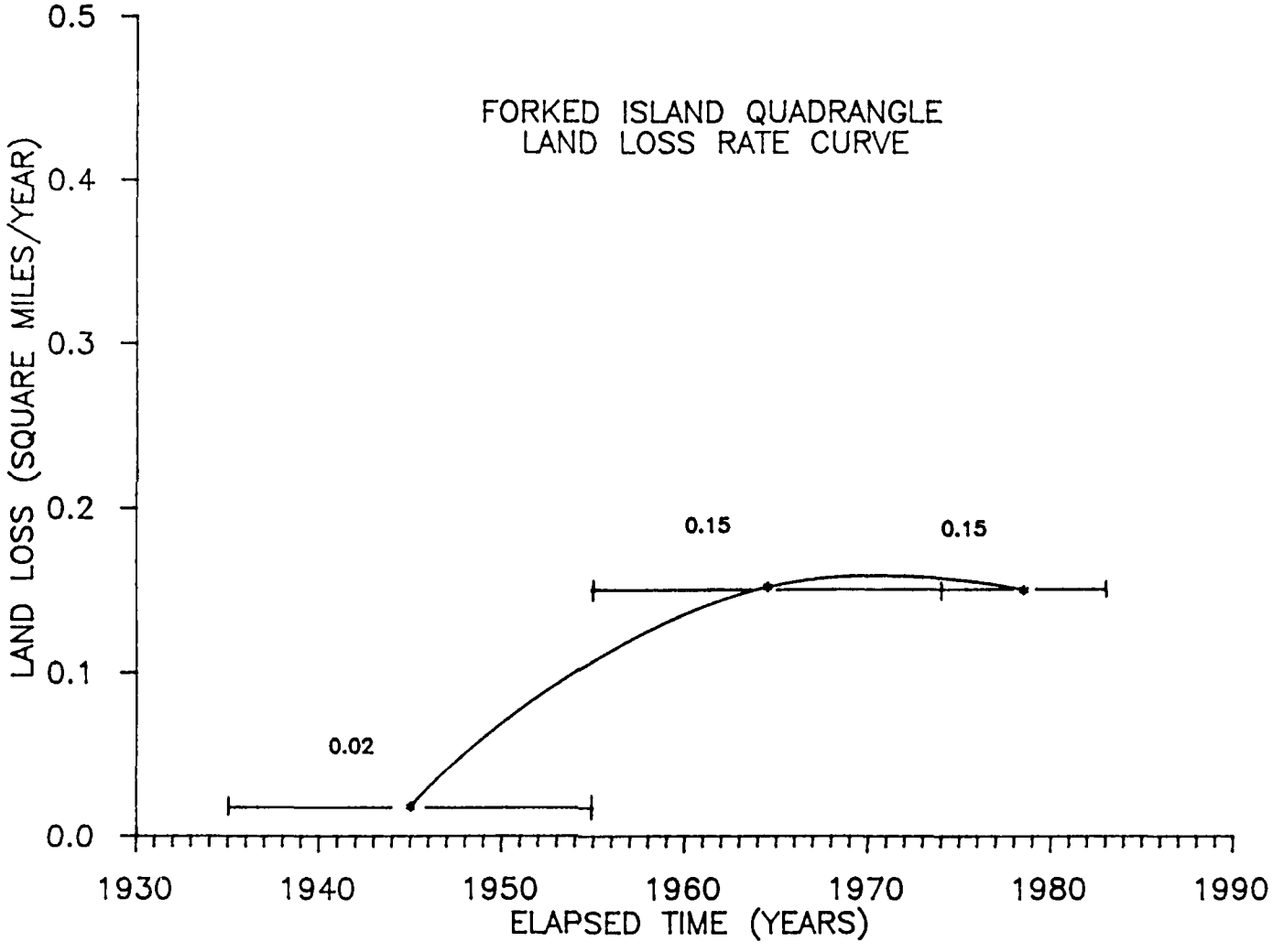
APPENDIX A: CHENIER PLAIN LAND LOSS RATE CURVES

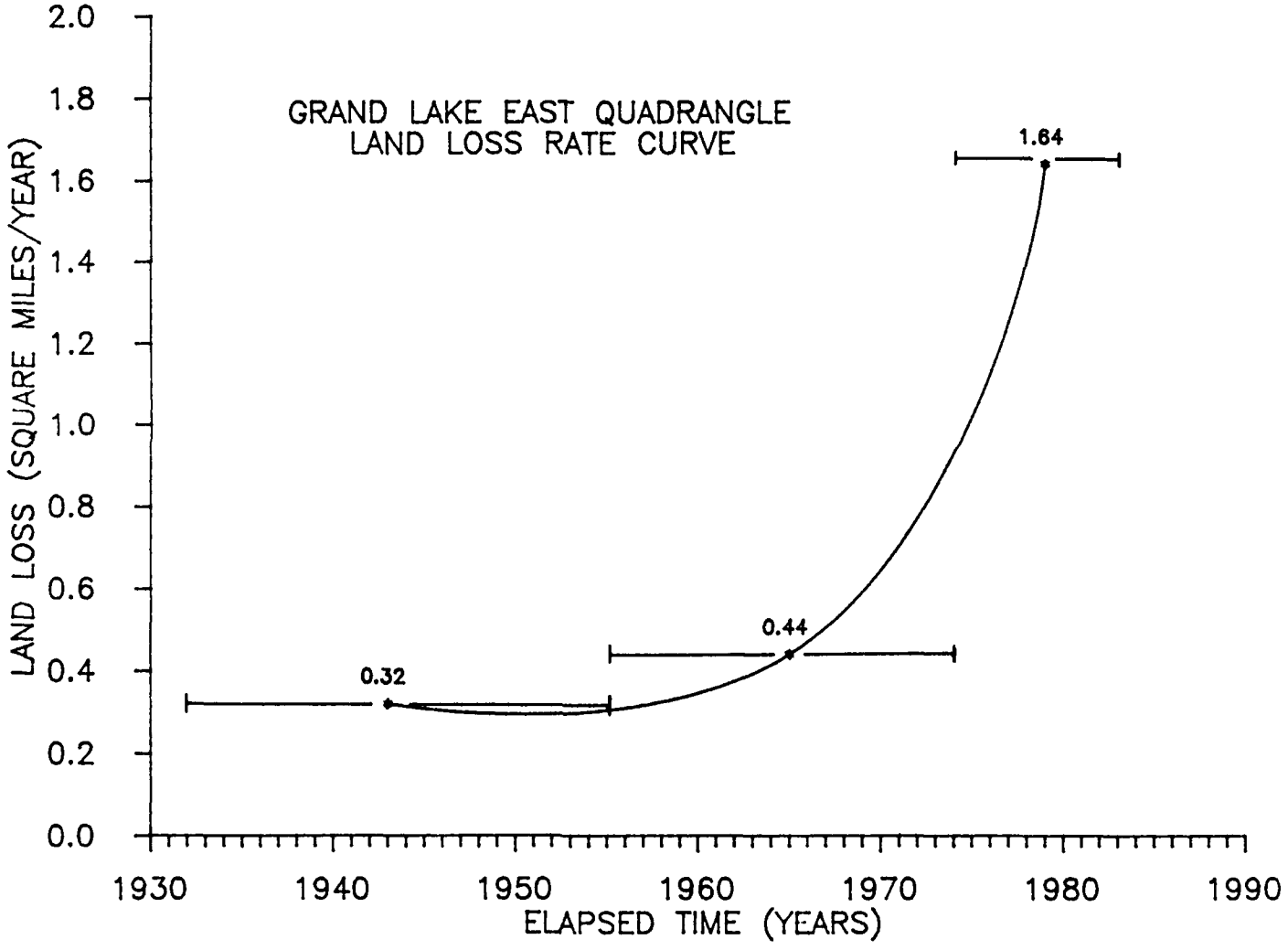

ABBEVILLE QUADRANGLE
LAND LOSS RATE CURVE
LAND LOSS (SQUARE MILES/YEAR)
0.5
0.4
0.3
0.2
0.1
0.0
0.08
0.25
0.26
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)

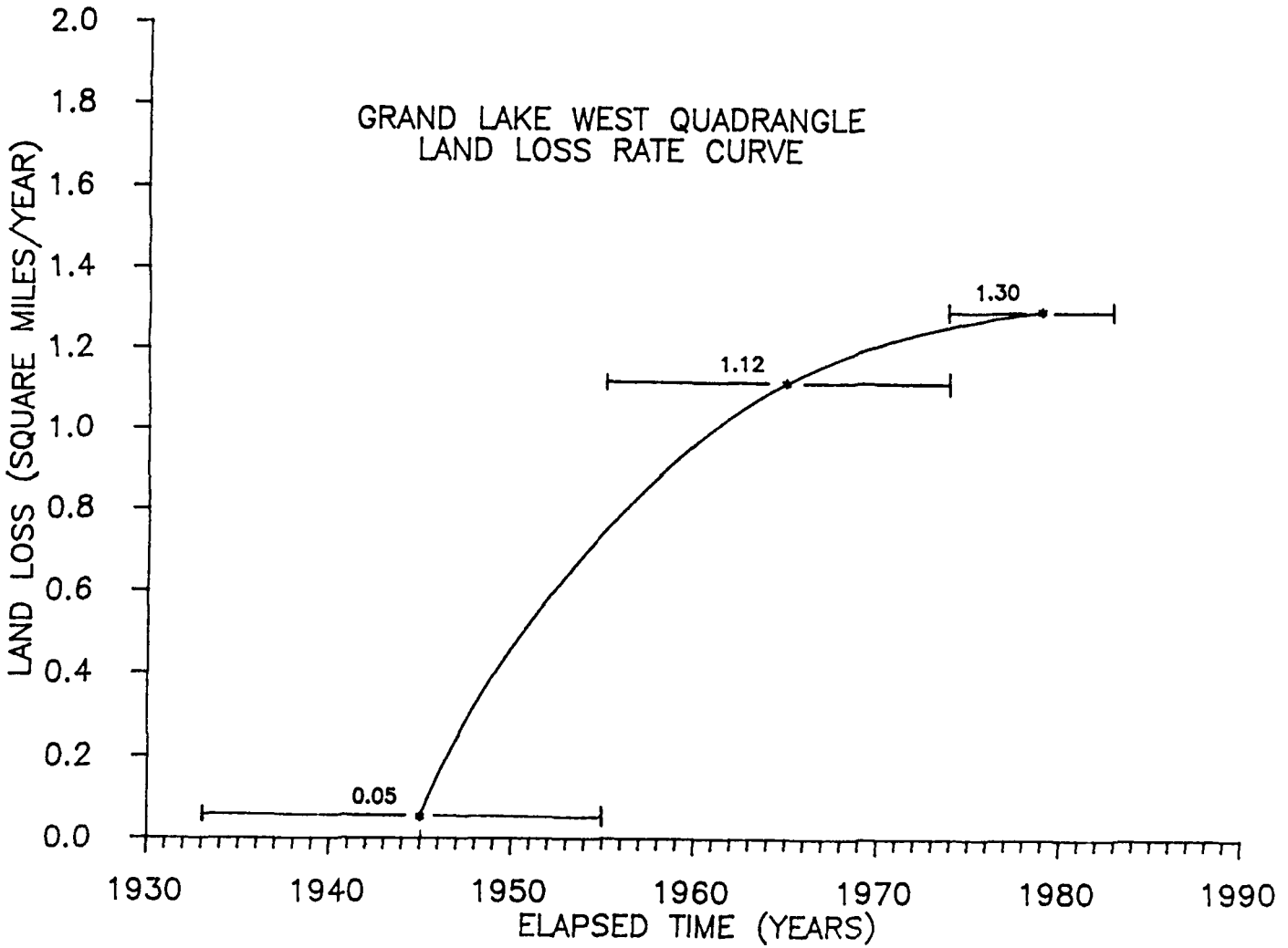

CAMERON QUADRANGLE
LAND LOSS RATE CURVE
2.47
0.60
0.08
3.0
2.0
1.0
0.0
LAND LOSS (SQUARE MILES/YEAR)
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)

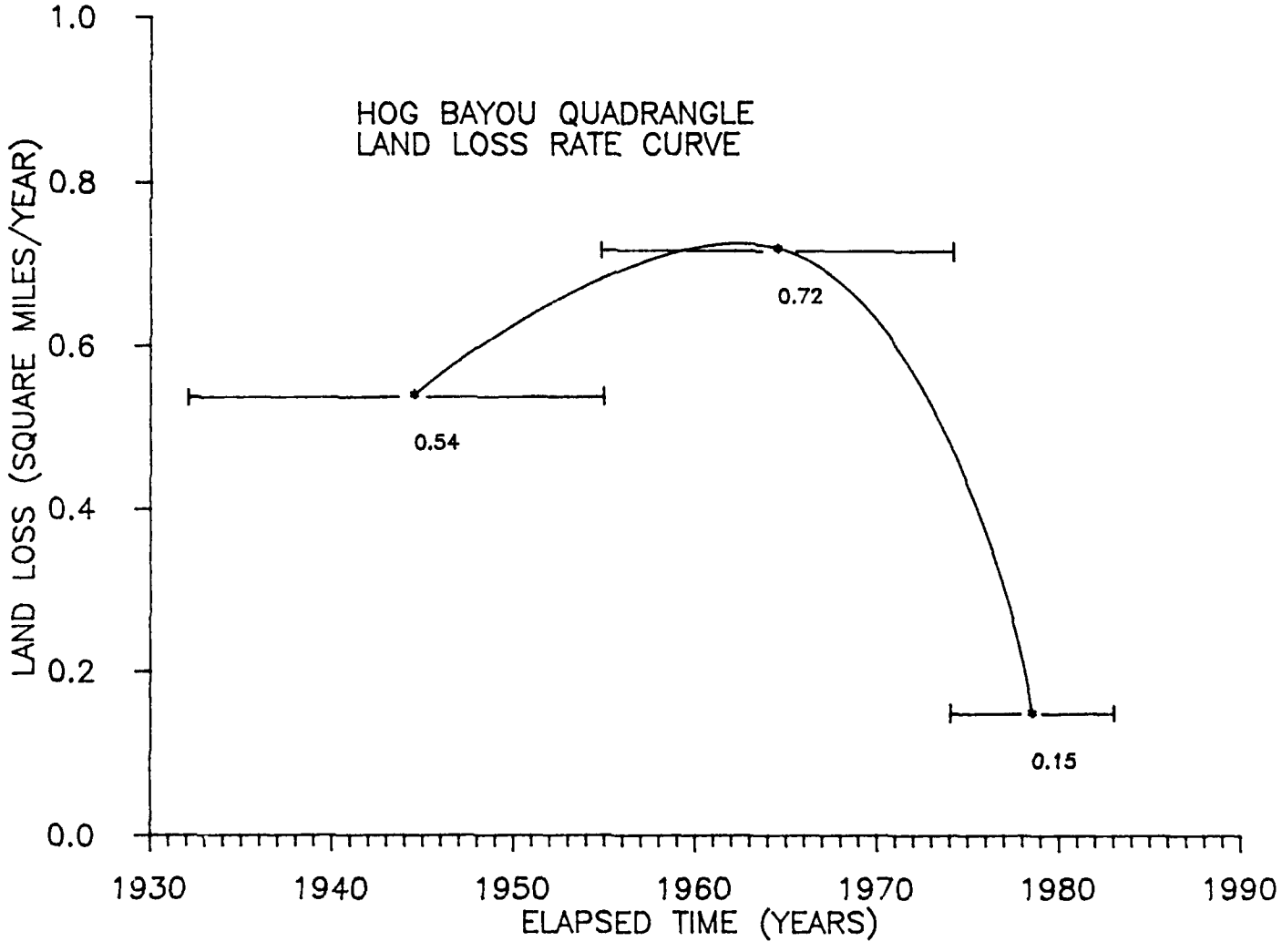

CHENIERE AU TIGRE QUADRANGLE
LAND LOSS RATE CURVE
0.36
0.13
0.08
LAND LOSS (SQUARE MILES/YEAR)
0.5
0.4
0.3
0.2
0.1
0.0
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)

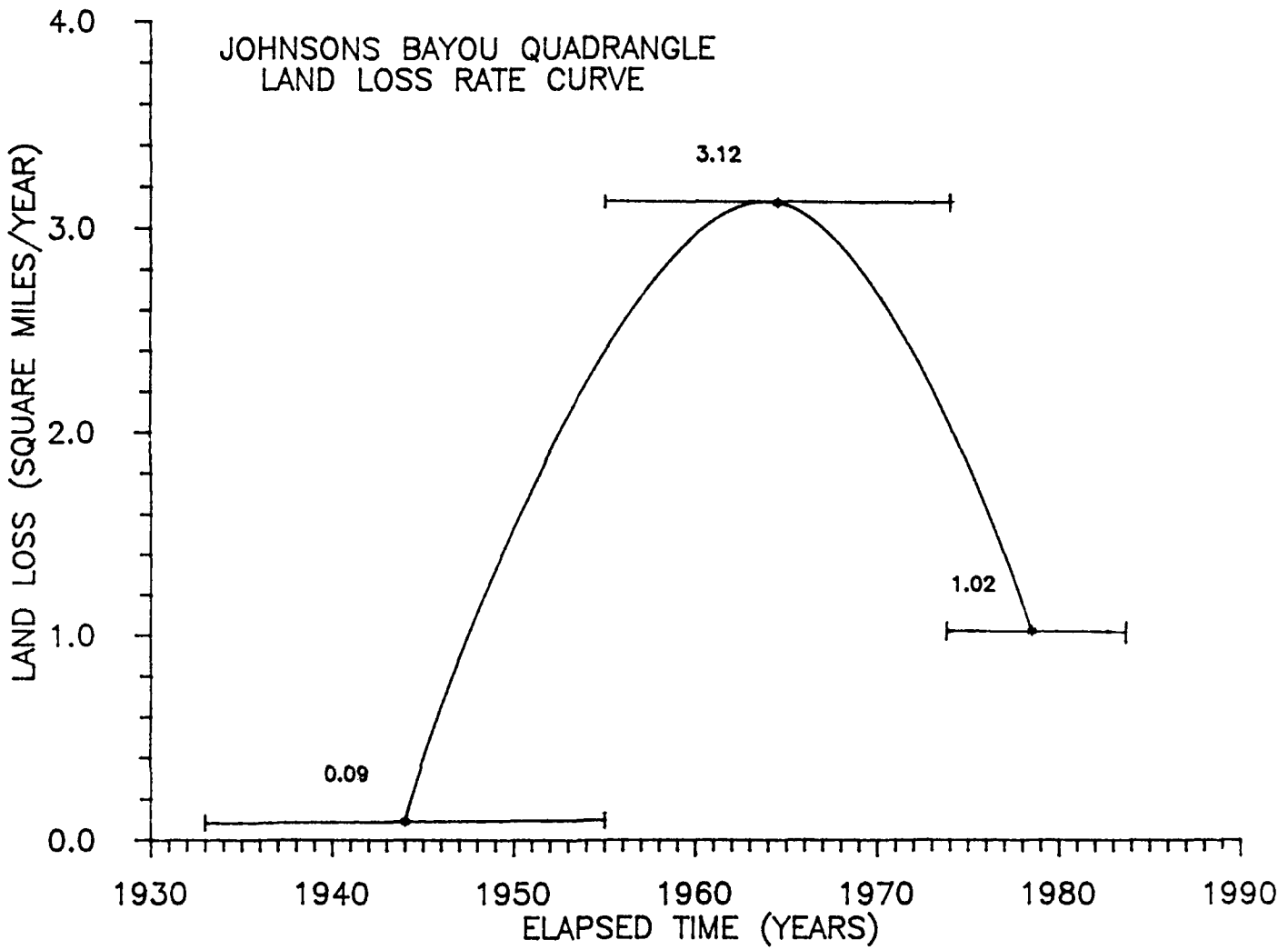

1.0
0.8
0.6
0.4
0.2
0.0
LAND LOSS (SQUARE MILES/YEAR)
0.64
0.82
0.50
CONSTANCE BAYOU QUADRANGLE
LAND LOSS RATE CURVE
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)

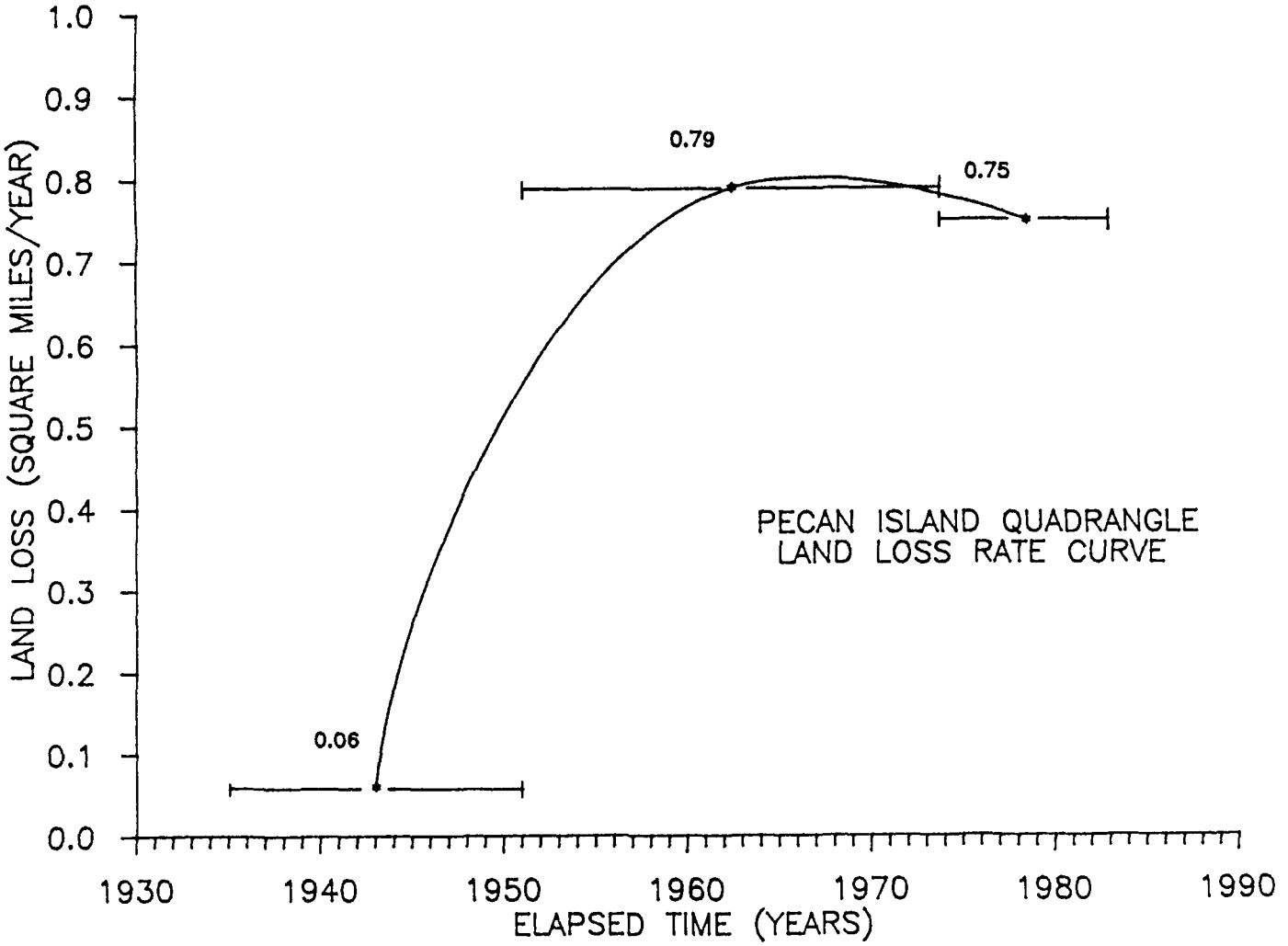

FORKED ISLAND QUADRANGLE
LAND LOSS RATE CURVE
LAND LOSS (SQUARE MILES/YEAR)
0.5
0.4
0.3
0.2
0.1
0.0
0.15
0.15
0.02
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)

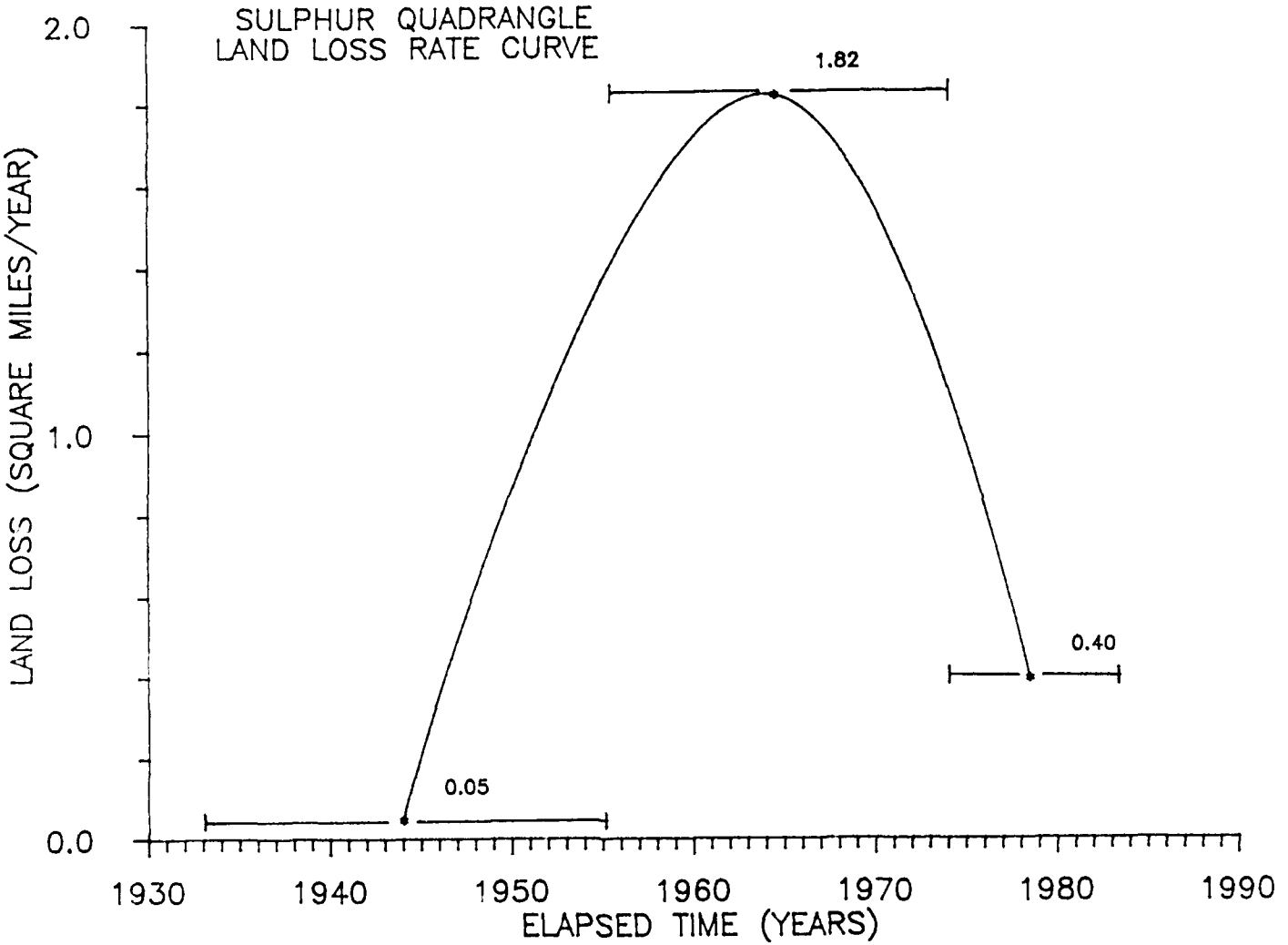

GRAND LAKE EAST QUADRANGLE
LAND LOSS RATE CURVE
LAND LOSS (SQUARE MILES/YEAR)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.32
0.44
1.64
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)

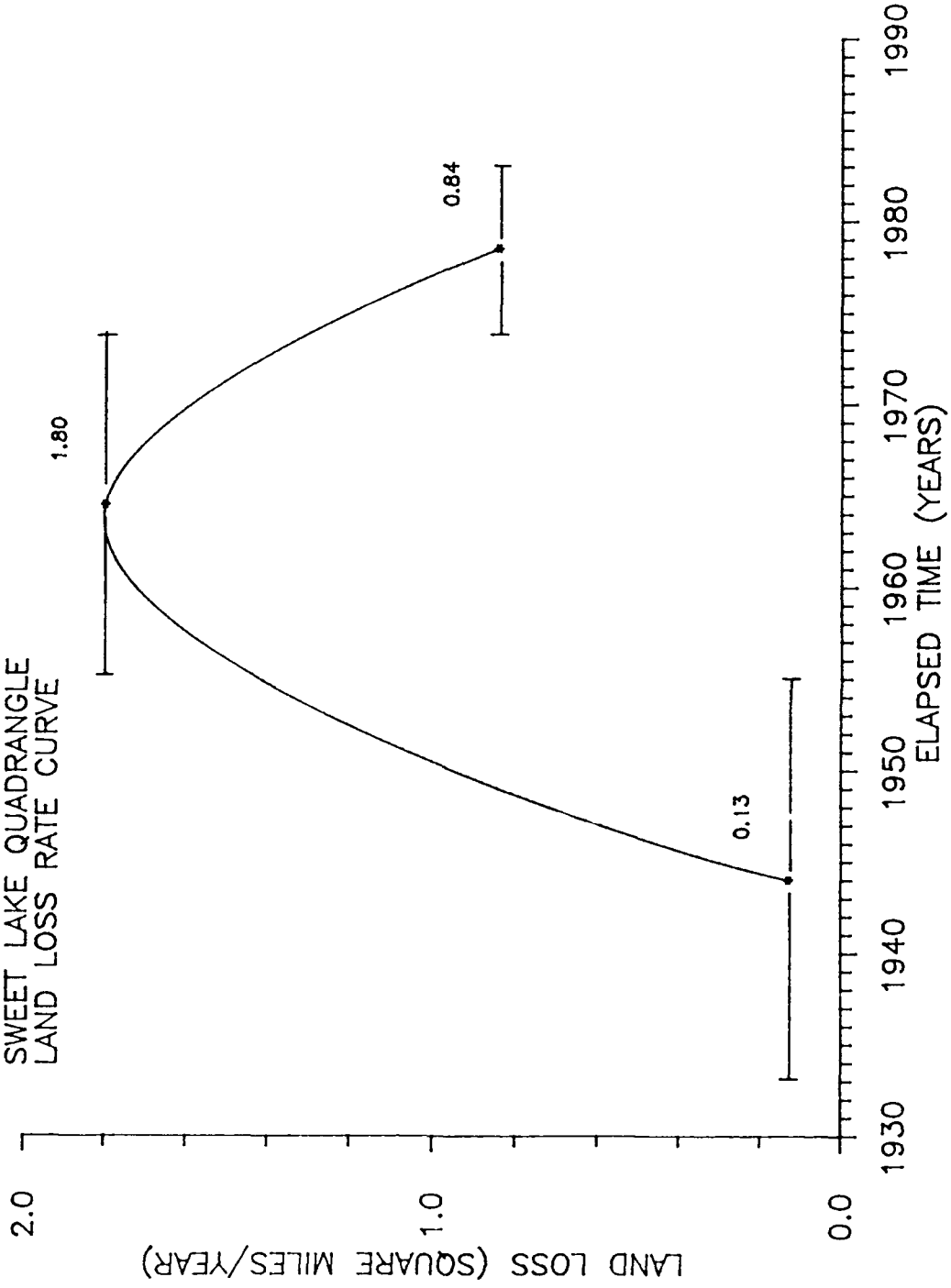

GRAND LAKE WEST QUADRANGLE
LAND LOSS RATE CURVE
LAND LOSS (SQUARE MILES/YEAR)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1.30
1.12
0.05
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)


HOG BAYOU QUADRANGLE
LAND LOSS RATE CURVE
LAND LOSS (SQUARE MILES/YEAR)
1.0
0.8
0.6
0.4
0.2
0.0
0.54
0.72
0.15
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)


JOHNSONS BAYOU QUADRANGLE
LAND LOSS RATE CURVE
LAND LOSS (SQUARE MILES/YEAR)
4.0
3.0
2.0
1.0
0.0
3.12
1.02
0.09
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
LAND LOSS (SQUARE MILES/YEAR)
0.79
0.75
0.06
PECAN ISLAND QUADRANGLE
LAND LOSS RATE CURVE
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)


SULPHUR QUADRANGLE
LAND LOSS RATE CURVE
2.0
1.0
0.0
LAND LOSS (SQUARE MILES/YEAR)
1.82
0.40
0.05
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)


SWEET LAKE QUADRANGLE
LAND LOSS RATE CURVE
LAND LOSS (SQUARE MILES/YEAR)
2.0
1.0
0.0
1930
1940
1950
1960
1970
1980
1990
ELAPSED TIME (YEARS)
1.80
0.84
0.13